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DIRECTIONAL REQUIREMENTS FOR AIRPORT RUNWAYS

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Members, ASCE

AIR TRANSPORT DIVISION

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PAPERS

DIRECTIONAL REQUIREMENTS FOR AIRPORT RUNWAYS

By Ralph H. Burke[1] and Harry Otis Wright, Jr.,[2] Members, ASCE

Synopsis

The layout of airport runways involves many problems that can be solved only by a thorough analysis of requirements at each specific location. The important factor of runway orientation can be influenced by the type of landing gear used on the airplanes. The effect of this factor and also the effect of cross wind are evaluated and discussed.

Attainment of maximum utilization of an airport is to a great extent dependent on the selection of a suitable layout. The variation of utilization factor with cross-wind velocity and landing gear characteristics is tabulated.

Suggestions are made concerning runway organization and the ability of an airport to meet the imposed traffic requirements.

Introduction

The purpose of this paper is to review the problem of directional requirements from the standpoint of the designer of airports. On the one hand, full cognizance must be taken of the policy of the Civil Aeronautics Administration (CAA) limiting runway construction to that required by capacity without consideration of wind directions. On the other hand, every effort must be made to meet the objective of the airlines which is to provide uninterrupted and dependable schedules of operation. A further element of importance to the designer of municipal airports is the balance of all the economic factors in order that the investment of public funds in airports will be fully justified on the basis of public benefits derived from their construction. A logical set of airport standards is necessary to meet this requirement.

Note.—Written comments are invited for publication; the last discussion should be submitted by April 1, 1952.

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Airport Standards

Airport requirements have undergone a series of radical changes during the relatively short history of aviation. In 1903, when the Wright brothers, Orville and Wilbur, launched the airplane "Kitty Hawk," and for the next decade or so, there were no airports. During the succeeding years, as speed, weight, and carrying capacity of airplanes were increased, prepared places to land became a necessity. Aircraft characteristics changed so rapidly that airports were outmoded almost as soon as they were built. Many localities had the sad experience of constructing airports that became obsolete or relegated to secondary use long before the expiration of a reasonable amortization period.

The CAA performed a long-needed service to aviation in adopting, as it did in 1947, standards as to length and load capacity of runways for the several classes of airports throughout the United States. Here, finally, was a yardstick to be used by the airport designer to measure the required facilities, and here also was a definite limit on the aircraft designers.

The so-called "one runway" policy of the CAA will further clarify the design problem for airports and aircraft. Stated in its simplest terms, the basis of the CAA policy is the theory that, if all aircraft were equipped with castering landing gears, the wind direction could be disregarded entirely; then only such runways should be built as would accommodate the volume of traffic at any certain airport. Since it would obviously be cheaper to equip all aircraft with castering gears than to build multiple runways at all airports, such a policy results in over-all economy.

History of the Problem

The entire problem of runway direction centers around the type of landing gear used on the aircraft, so a brief review of the history of the development of landing gear is pertinent at this point. It should be understood that landing gear is a necessary evil. This gear is a detriment to any aircraft while in the air. Its sole function is to safely permit loss of speed on landing and acceleration on take-off and to permit some measure of maneuverability for the aircraft in taxiing on the ground.

Greased rails were used for the take-off in the first aeronautical experiments. Then skids, with the addition of a pair of wheels, were tried. Later, at about 1910, 3-wheeled or 4-wheeled arrangements were used. These later applications overcame the excessive ground frictions of the earlier skids on take-off, but were inefficient in decelerating on landing.

In 1924 E. Stinson pioneered the installation of brakes on the main wheels, thus contributing a great advance in ground control. Skids were no longer needed, either for drag or directional stability. Prior to World War II the tricycle gear was revived, since it was less susceptible to ground looping and produced the desirable characteristic of a level cabin floor while the airplane was on the ground. The tricycle gear, with steerable nose wheel, has become the most commonly used landing gear on transport aircraft. The latest

development is the castering gear. It has been built and tested for small aircraft of various types and also for the DC–3. Record of its application to larger aircraft has not yet appeared.

Granting the feasibility of the universal application of castering gear to all aircraft, there remains an analysis of the over-all economy, dependability of service, and capacity of the airport to determine whether such an application justifies the acceptance of the CAA policy.

Cross–Wind Problem

Cross wind is of significance only when the airplane is in contact with the ground. When flying, wind direction or intensity in the absence of sudden gusts does not affect the maneuverability or control of an airplane. As the airplane approaches the ground, however, it is flying at some angle of crab depending upon the magnitude and direction of the cross wind and the speed and direction of flight. If the resultant angle of crab is small (less that 15°), no problem exists, for at the instant of contact the noncastering landing gear will track immediately and the wheels will roll readily. If the resultant angle of crab is large, the wheels of the landing gear must skid sideways causing severe overloads and possible failure of the mechanism.

To illustrate, a plane with a speed of 100 miles per hr at touchdown, operating under a 20 miles per hr cross-wind component, is flying at an angle of crab of 11½°. This is a relatively safe condition. If the plane has a speed of only 75 miles per hr and encounters a cross wind of 50 miles per hr, the angle of crab is 43°, and a dangerous condition exists.

Since 1938 the cross-wind problem has become less critical in regard to adequate control after contact. New developments, such as tricycle landing gear with steerable nosewheels in multi-engine planes, the ability to use more power on one side than on the other, and reversible pitch propellers have made it much easier to control the plane, and the margin of safety has been raised considerably. The Air Transport Association permits aircraft with noncastering landing gear to operate in cross winds with velocity up to 20 miles per hr at a 90° angle to the runway.

Under this ruling the utilization of any airport depends upon the number or runways and the percentage of the time when the cross-wind component relative to any available runway exceeds 20 miles per hr. Assuming the wind rose at Chicago, Ill., to be fairly typical, a single runway airport could be used 96% of the time and a 2-runway airport (with the runways at right angles) could be used 98.1% of the time. A standard 4-runway airport could be used 99.9% of the time.

As a result of exhaustive tests, the CAA will permit operation of planes of DC-3 type equipped with castering landing gear in cross winds up to 40 miles per hr. Using this criterion, with wind conditions that prevail in Chicago, a single-runway airport could be used 99.0% of the time and a 2-runway airport 99.9% of the time. A 4-runway airport would be useable practically 100% of the time. The percentage of utilization of various types of airports with noncastering and castering gears at various cross winds is given in Table 1.

The differences in utilization of an airport as shown in Table 1 may seem small, yet a difference of only 4% will affect regularity and dependability of service to such a degree that, in scheduled flights at least, it spells the difference between an acceptable mode of travel and a totally inadequate service.

Therefore, in the large airports, including all those at which scheduled passenger service is maintained, practically 100% utilization is a necessity. The question remains whether the result can be most economically obtained by multiple runways or by the universal application of castering gears. The CAA has estimated that it would cost about $10,000,000 (1950) to equip all of the approximately 1,100 planes now in scheduled operation with castering gears. This figure does not include lost income during the conversion period. This estimate seems low, but even if the figure were doubled the situation would not be seriously altered. This figure must be compared with the average total cost of a runway of $3,000,000 including land acquisition, drainage, grading, and other incidentals. Since there are over 780 airports of Class IV or larger in the United States, the evident conclusion is that the universal application of castering gears will amount in cost to only a small fraction of the cost of added runways.

TABLE 1.—USEABLE PERCENTAGE OF TOTAL TIME AT AN AIRPORT[a]

Allowable cross wind (miles per hr)	Type of landing gear	Number of Runway Directions		
		One	Two	Four
(*a*) Aircraft Landing at Approximately 40 Miles per Hr				
10.0	Noncaster	61.2	74.4	91.6
22.5	Caster	98.6	99.4	99.9
(*b*) Aircraft Landing at Approximately 55 Miles per Hr				
15.0	Noncaster	91.4	95.1	99.9
32.5	Caster	98.9	99.8	100.0
(*c*) Aircraft Landing at Approximately 70 Miles per Hr				
20.0	Noncaster	96.0	98.1	99.9
40.0	Caster	99.0	99.9	100.0

[a] Based on conditions at Chicago, Ill.

Airport Utilization

As seen in Table 1, a 4-runway airport can be used by aircraft with noncastering gear 99.9% of the time in Chicago. Castering gears would raise the utilization to practically 100%. In fact, Chicago Midway Airport in all its history has never been closed to traffic because of high adverse winds alone. If Chicago had a single direction runway airport, even aircraft with castering gear could operate only 99.0% of the time. This difference, even though appearing small when expressed in percentage, is vital in determining dependability of air travel, for it means that for a total of over 3 days per yr the Chicago airport would be unable to operate as far as air travel is concerned. These occurrences are of sufficient duration as to affect the continuity and seriously disrupt scheduled operations. The policy of single directional runways cannot be seriously considered for such airports as Chicago.

Applying the results of Table 1 to the operation of small aircraft, such as the type that can safely operate with noncastering gear at cross winds of 10 to 15 miles per hr, a vastly different picture appears. On single-runway airports (such as Meigs Airport, Chicago's downtown air strip) the addition of castering gears to the light planes that use the field raises the utility of the airport from 61.2% to 98.6% for aircraft limited to a 10 miles per hr cross-wind landing with noncastering gear. Similar increases in utilization are noted in the case of aircraft having higher landing speeds. These increases are significant and will result in marked improvement of efficiency of the air strip. Meigs Airport is licensed for operation only when the cross wind is below 15 miles per hr.

Traffic Requirements

Under the CAA policy, the salvation of larger airports might very well lie in the words "Additional runways will be approved only where required to handle the volume of traffic." Assuming a traffic requirement of 60 plane movements per peak hr at a major airport (and few airports exceed this figure), how many runways are needed? In fair weather 1 runway can handle one plane movement per min, or 60 movements per hr. An analysis of peak hour requirements, however, must include the characteristics of the peak and the weather conditions. Records show that 60% or 36 movements will occur 20 min and will consist, on the average, of 24 arrivals and 12 departures.

Under adverse weather conditions, even with such navigational aids as ground-controlled approach, instrument landing system, and high intensity lighting, the landing rate drops to 1 airplane every 3 min. Thus, the 24 arrivals in 20 min will require 4 runways, although 1 more runway is needed for the 12 departures. A total of 5 runways are, therefore, needed to accommodate 60 plane movements per peak hr. A further argument for multiple runways is the fact that air traffic is expanding, and it can reasonably be expected to result ultimately in at least 3 times the present number of plane movements. On the other hand, the further development of electronic aids will doubtlessly decrease the interval between plane movements. These two elements tend to compensate for one another.

Considering all the elements, multiple runways should be built to meet traffic requirements under adverse weather conditions, and such runways should be nonintersecting, so as to allow their simultaneous use. Far from being wasted, such runways will not only provide adequate wind coverage for planes that are not equipped for safe operation under high cross winds, but also will provide the extra capacity for the inevitable growth of aviation when future planes are equipped so that cross winds can safely be disregarded.

Summary

A definite trend exists toward a greater tolerance as to cross winds. This has been brought about partly by higher landing speeds of large aircraft, resulting in a decreased angle of crab in landing and partly by the general use of tricycle landing gear with steerable nose wheel. This trend will be widened as the use of castering gear expands. Castering gear appears of greater advan-

tage to small planes. Its general use on small planes will greatly increase the utilization of single-strip airports. When castering gear has been demonstrated as practical for larger planes, it will increase their ability to serve single-strip runways, but not to a point at which definite schedules can be guaranteed.

Major airports at which the importance of dependable scheduled operation is paramount and at which the CAA authorizes such navigational aids as ground-controlled approach, instrument landing system, and high intensity lighting to provide uninterrupted service still require multiple runways for safe operation under peak load conditions. Multiple runways in a nonintersecting pattern will provide for present safety and high utilization and also will prove adequate for future traffic expansion. The CAA policy if applied realistically as to traffic requirements at major airports will, therefore, be beneficial. It will especially aid small aircraft operating on single runway airports and will hasten the day when improved landing gear on large aircraft will increase the capacity of major airports.